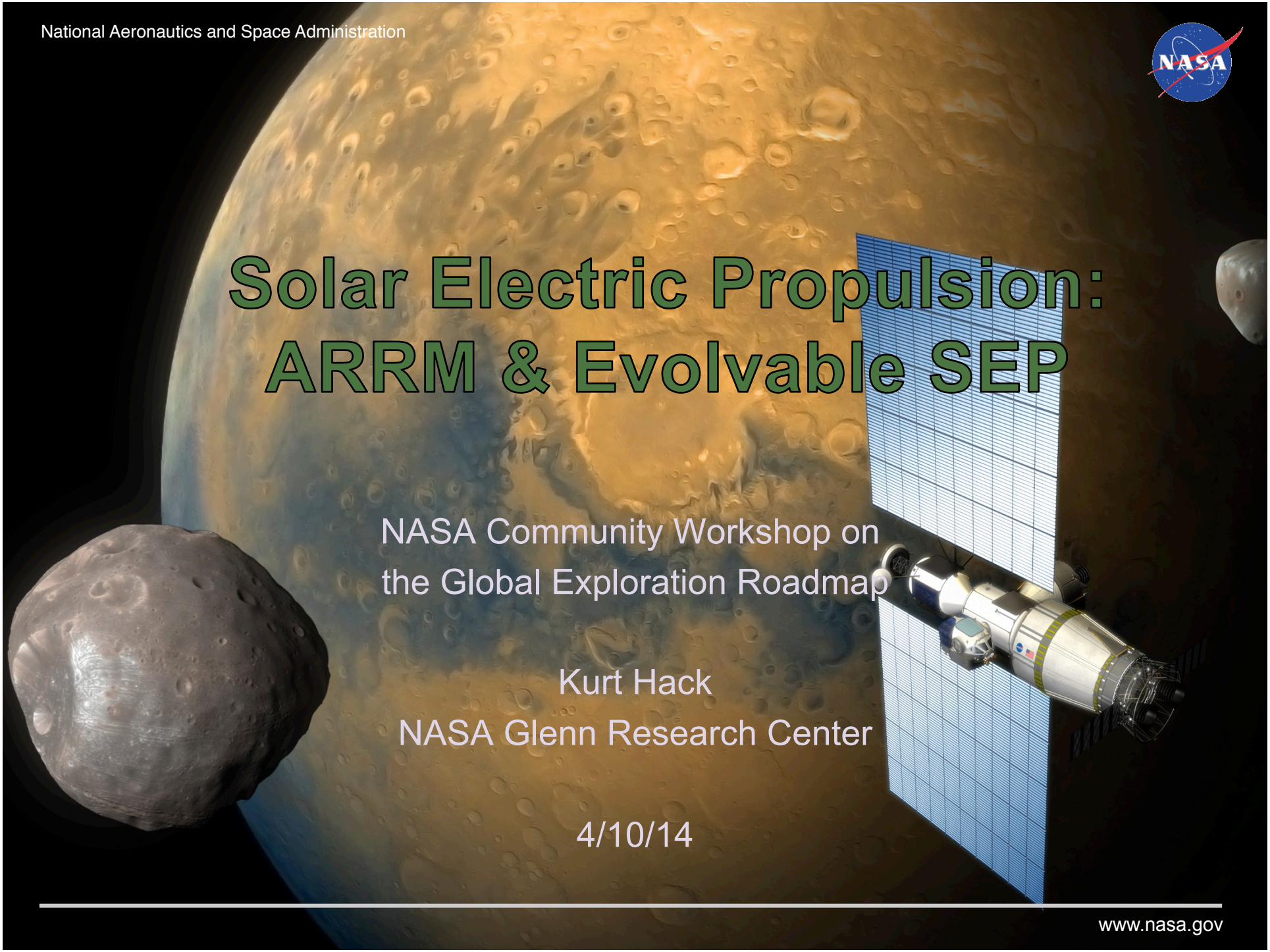


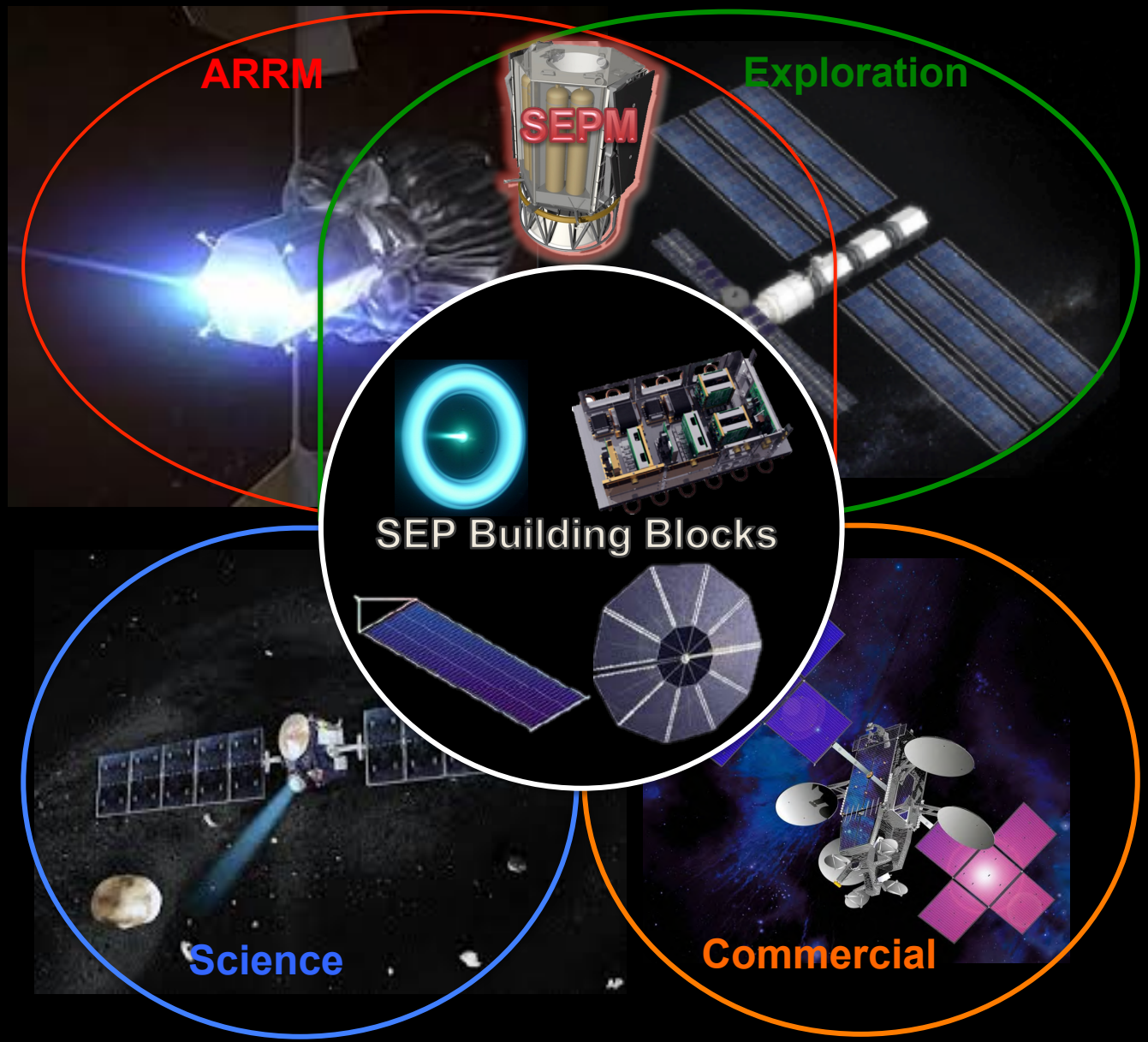
Solar Electric Propulsion: ARRM & Evolvable SEP

NASA Community Workshop on
the Global Exploration Roadmap

Kurt Hack
NASA Glenn Research Center

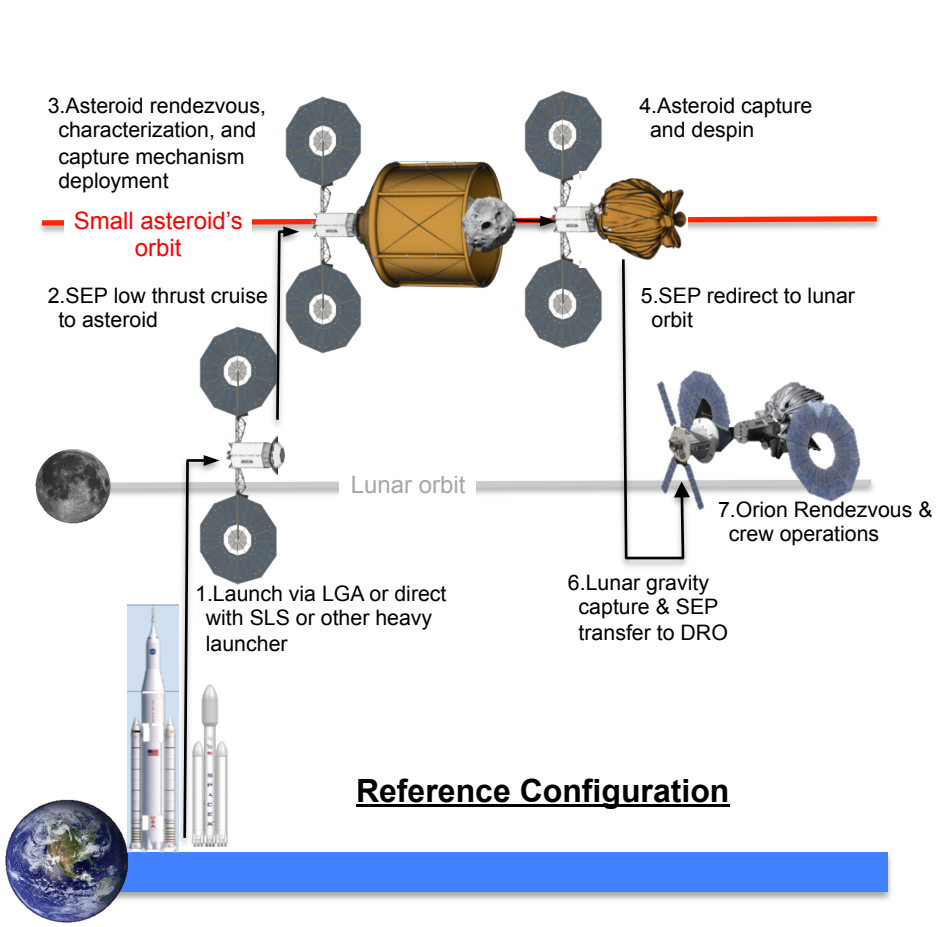
4/10/14

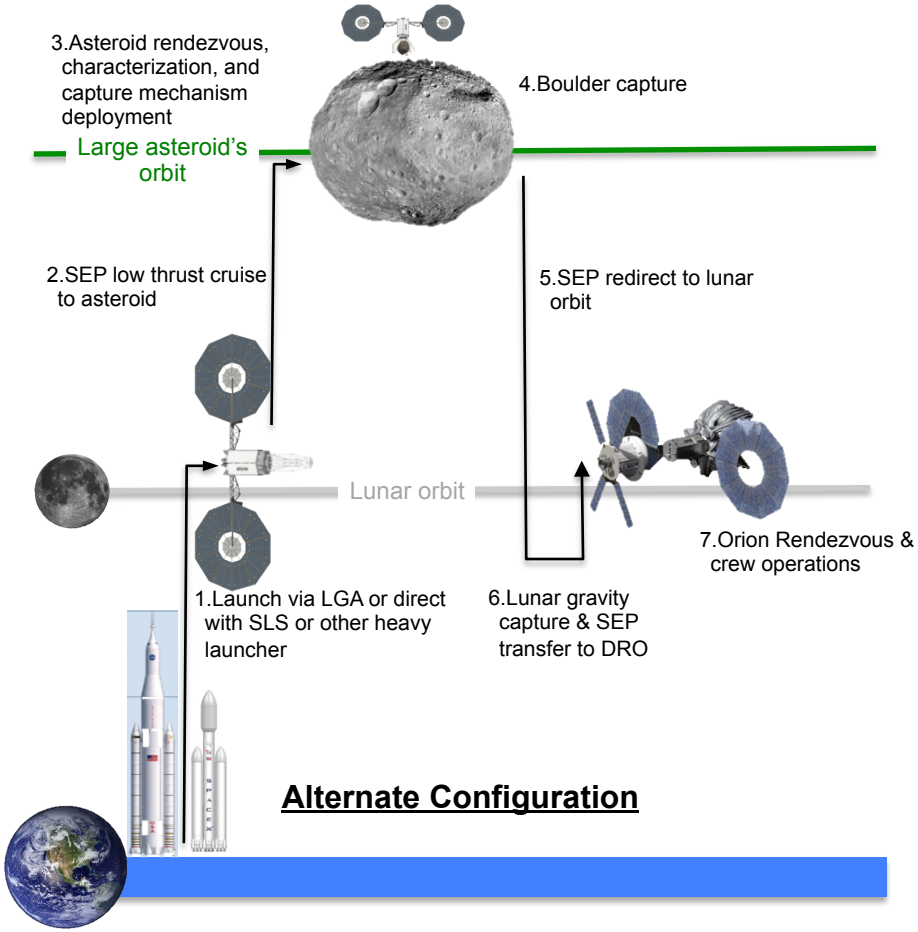
SEP Cross-Cutting Applications



Asteroid Robotic Redirect Mission Concepts

- NASA developing concepts for demonstrating initial SEP capability:
  - Reference concept: captures small, free-flying asteroid in the ~3-10m range
  - Alternate concept: captures a 1-4 meter boulder off a large asteroid



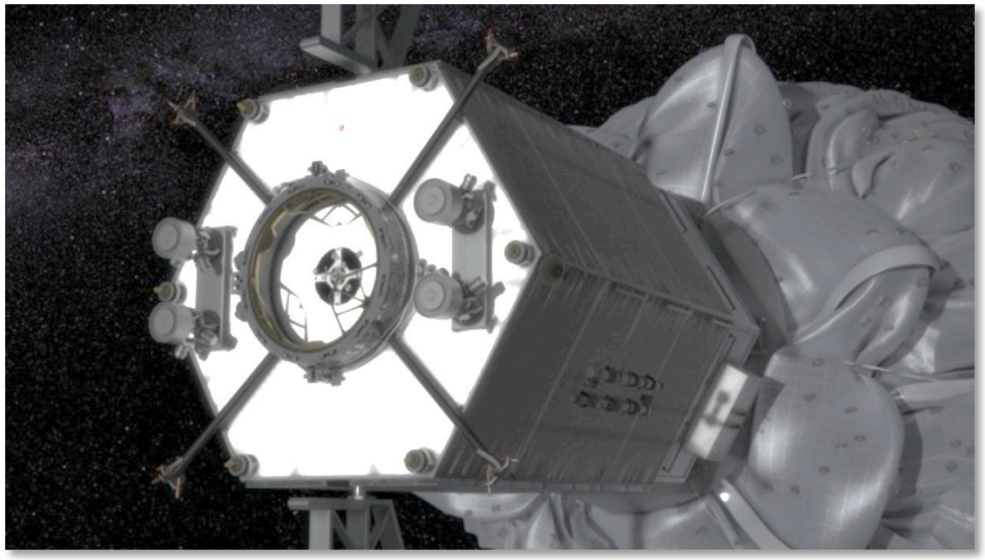


Both concepts based on a 50kW SEP spacecraft

ARRM Spacecraft SEP Module Concept

- Asteroid Redirect Vehicle (ARV) reference configuration developed
- SEPM is modular element of the ARV based on max capability with new tech currently under development

- **Solar Array**
- **EP Subsystem**
- Xe Storage
- PMAD
- TCS
- RCS
- Mechanical Subsystem



Reference configuration

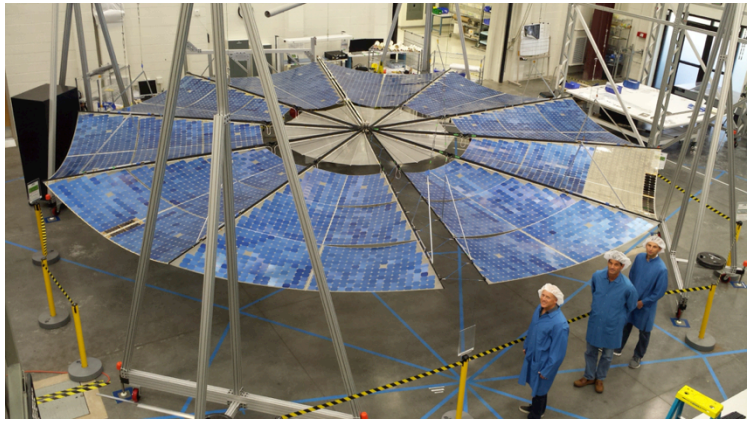
40 kW (3+1 -13.3kW strings) electric propulsion subsystem; $I_{sp} \leq 3000s$
≤10,000 kg of Xe in 8 – 0.5m x 3.3m seamless-aluminum lined COPVs
2 - 25kW (BOL) SA Wings compatible ≥ 6 yr deep space operation

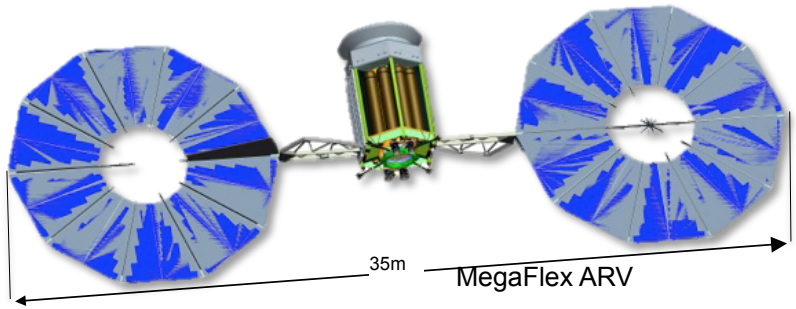
Solar Arrays & Electric Propulsion technologies currently under development

Solar Array Systems Development

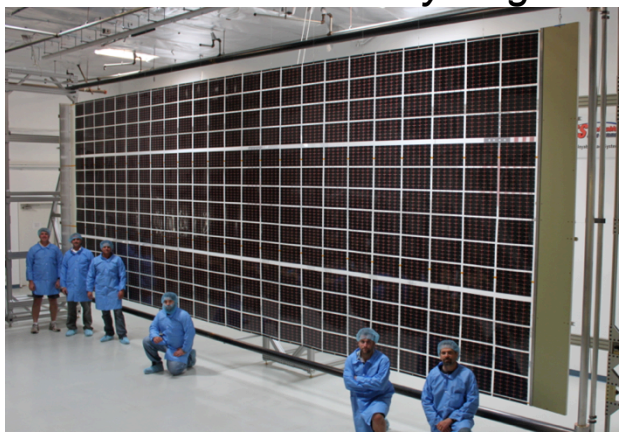
- Two different 15-25kW Solar Array Wing concepts are being developed:

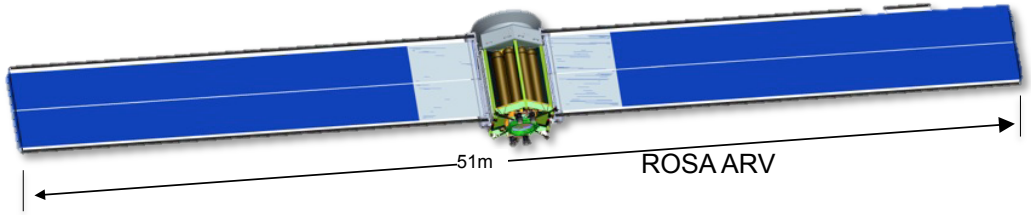
MegaFlex Solar Array Engineering Development Unit - ATK Aerospace





Roll Out Solar Array Engineering Development Unit - Deployable Space Systems

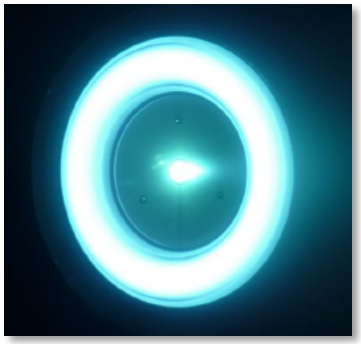




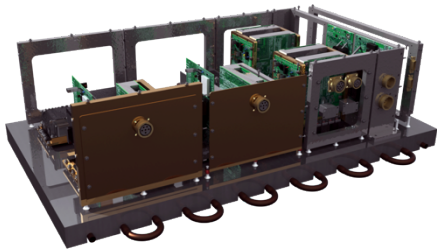
Low-mass, low-cost solar arrays extensible to higher powers

Electric Propulsion Development

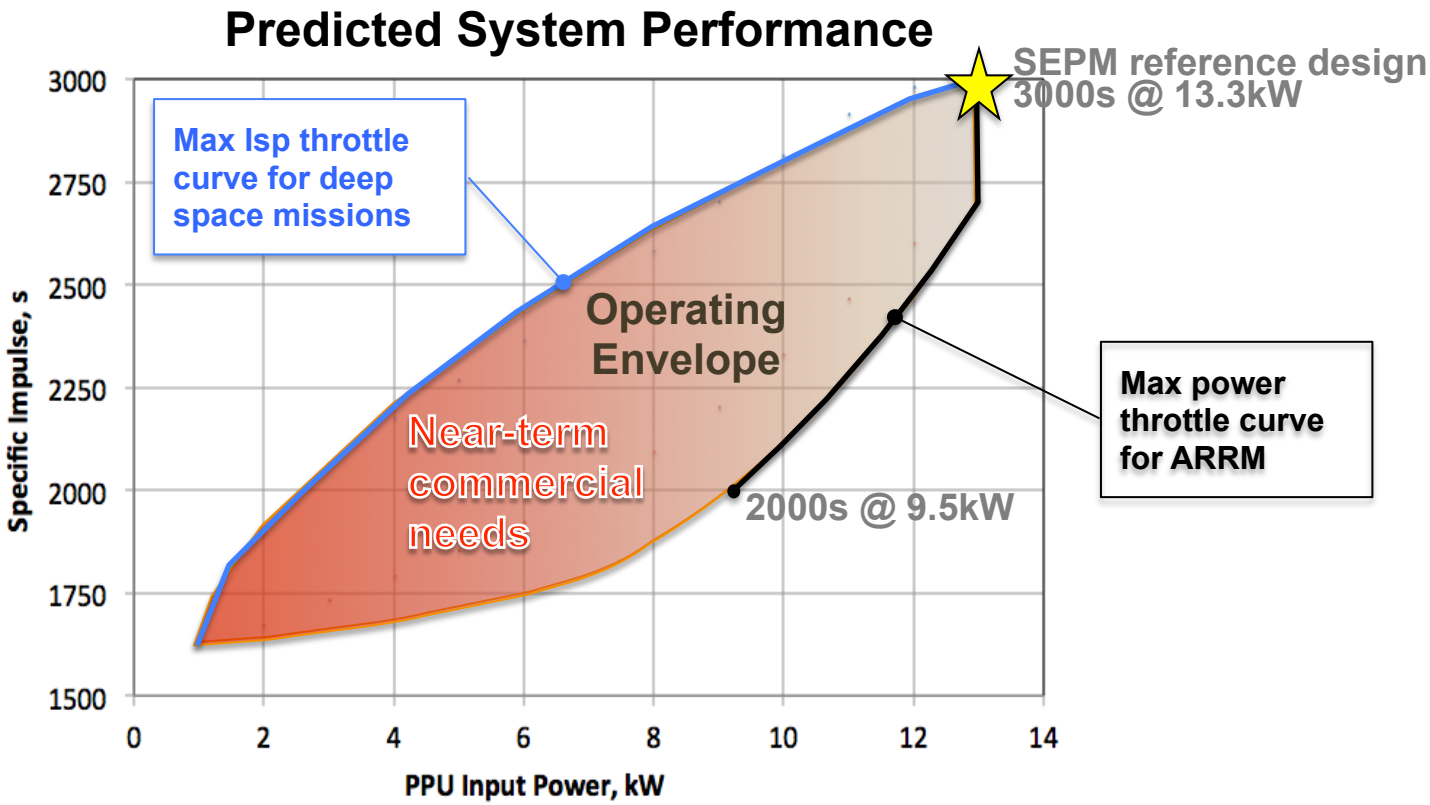
- 13kW Hall thruster propulsion subsystem under development
- Subsystem designed to have cross-cutting applicability



Magnetically shielded thruster



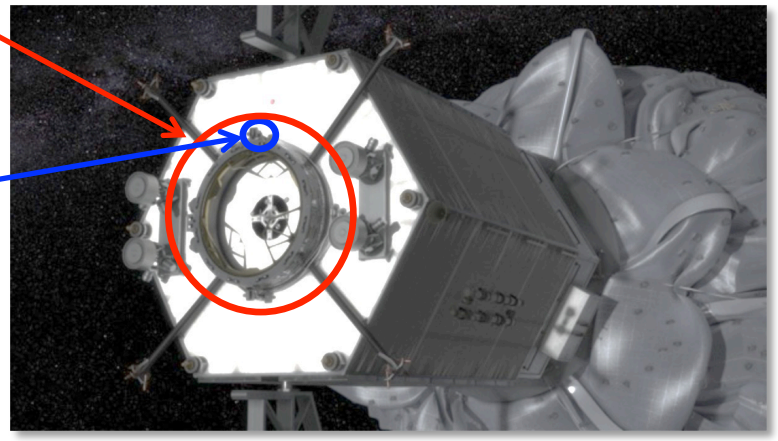
Brassboard Power Processing Unit



NASA developing high-power, high-specific-impulse, long-life EP technology with extensibility to higher powers

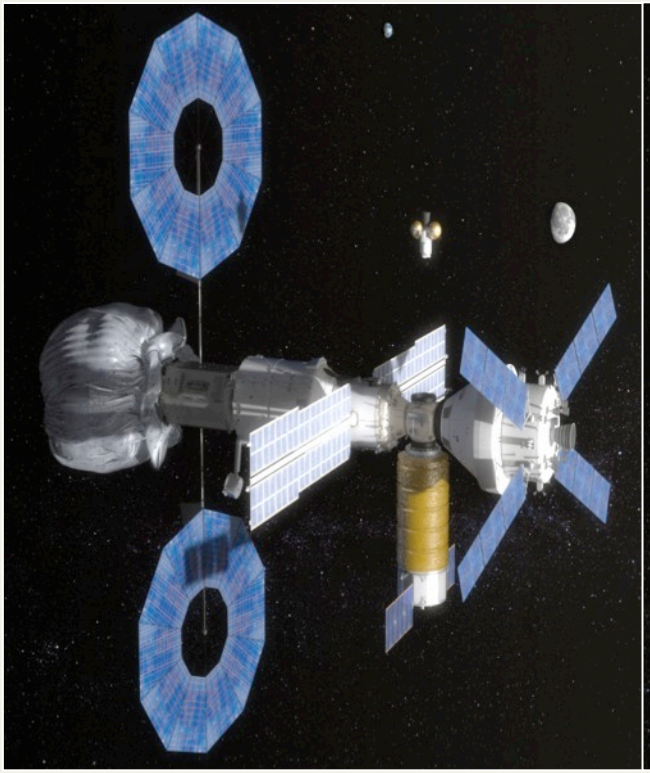
Approaches for Evolution of SEP

- Options include:
  - Include future needs in initial vehicle
    - E.g.: Added docking ring to aft of ARV
  - Scar initial vehicle to allow use in extended applications
    - E.g.: Power transfer to other exploration vehicles
  - Block-upgrade approach keeping same family of fundamental SEP systems
    - Following charts
  - Modular SEP where multiple ARRM-derived SEP elements can be combined
    - Following charts

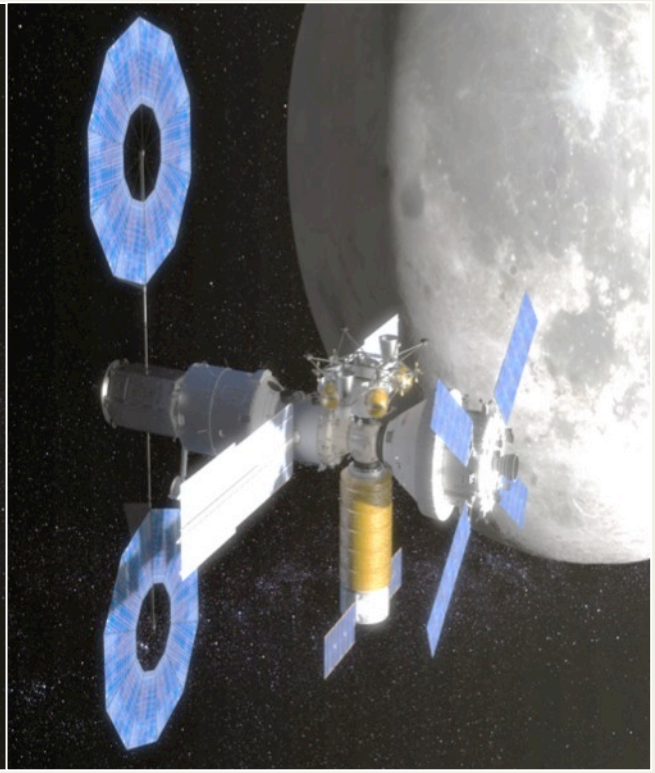


Trades on-going to find best fit of approaches for future uses within ARM constraints

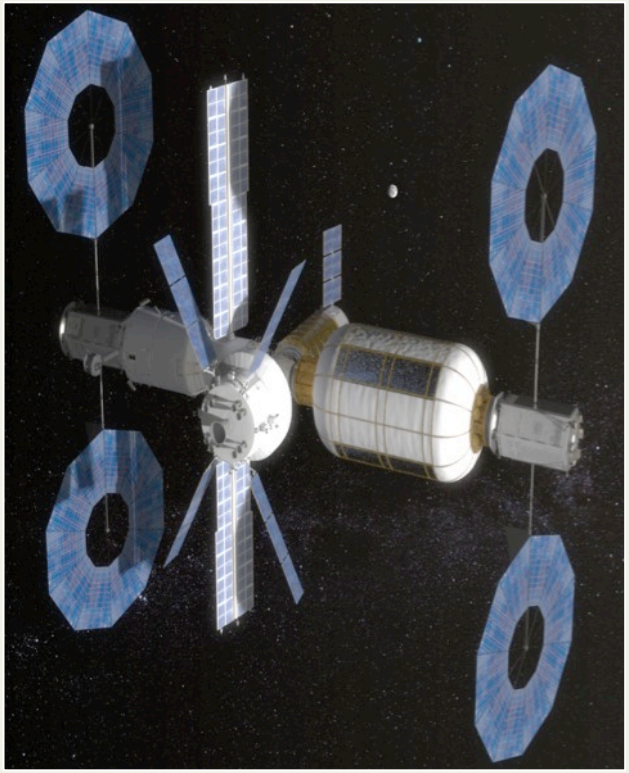
Asteroid Redirect Mission Builds upon Orion/SLS to enable Global Exploration Roadmap



Asteroid Exploitation Missions

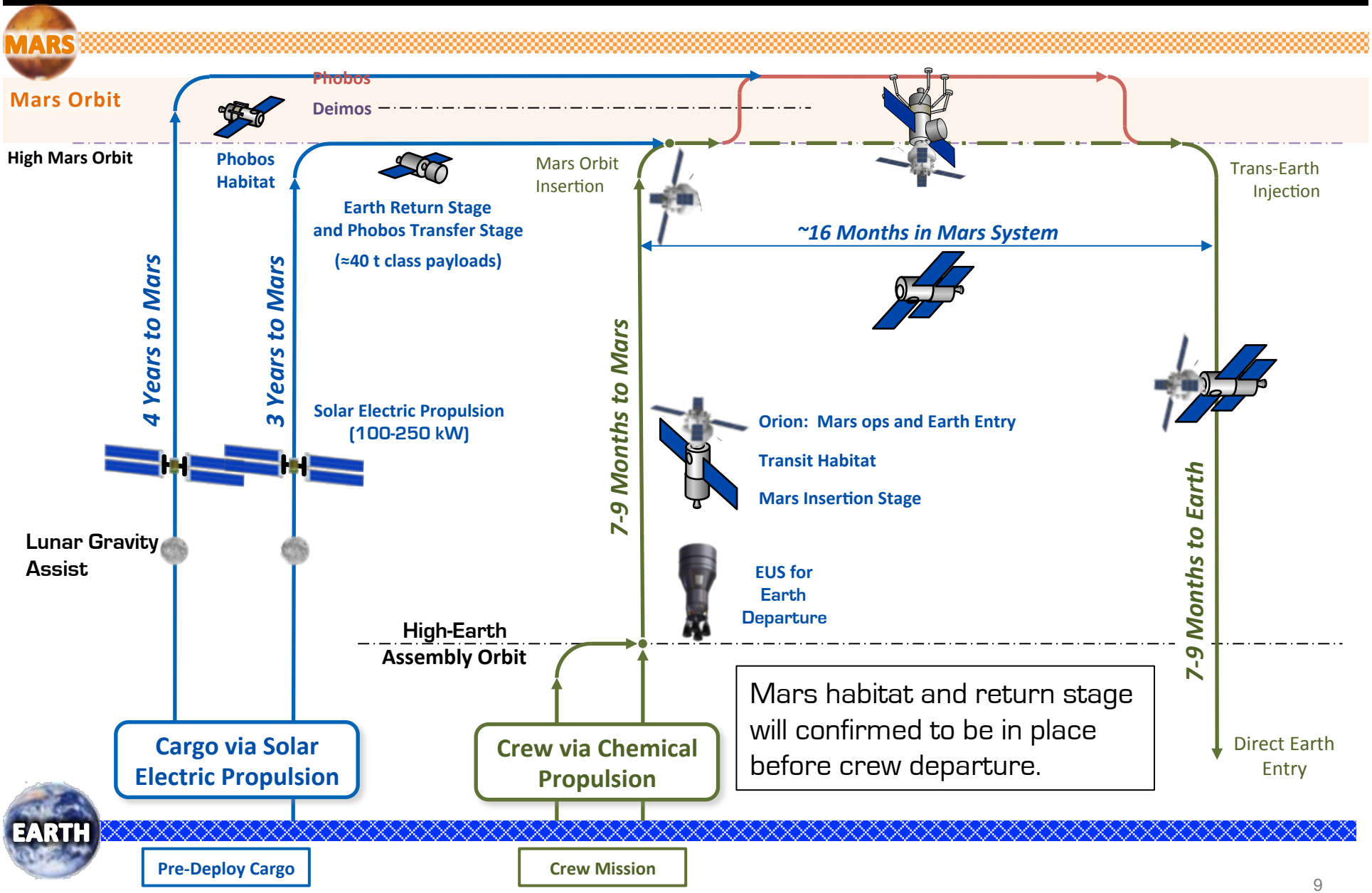


Lunar Vicinity Missions



Deep Space Missions

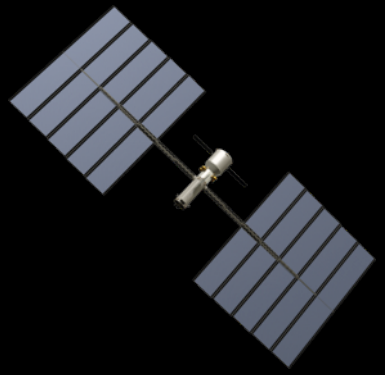
Notional ARM Derived Phobos Mission Option



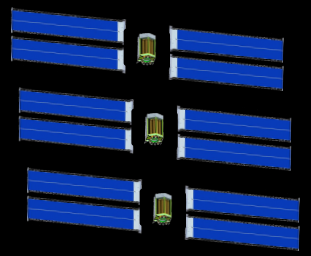
Use of ARM-derived SEP for Mars

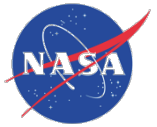
- Previous assessments have shown that human Mars missions utilizing a single round-trip monolithic habitat requires very high power SEP (approaching **1 MW total power)**
- As part of on-going Mars architectures analysis, we are developing scenarios that have evolvable ARM SEP supporting cargo delivery for human missions into deep space and the Mars Surface
  - Pre-deploy crew mission assets to Mars utilizing highly-efficient SEP, such as
    - Orbit habitats: Supports crew while at Mars
    - Return propulsion stages or return habitats
    - Exploration equipment: Unique systems required for exploration at Mars
  - High thrust chemical propulsion for crew
    - Crew travels on faster-transit, minimum energy missions: 1000-day class round-trip
    - Low-thrust SEP too slow for crewed Mars missions

One Very Large SEP



Multiple ARM derived SEPs (100-250 Kw Class)





Summary

- NASA pursuing high-power solar electric propulsion to support range of future human exploration architectures
- A solar electric propulsion module is part of the reference configuration configuration for the Asteroid Redirect Vehicle
- Developments of extensible 25kW-class solar arrays and 13kW class EP underway to support NASA's future needs
- These investments are designed to be cross-cutting to support additional SEP applications